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Comparison Of Nutrient Losses By Harvesting And Site Preparation Practices
In The Georgia Piedmont And Coastal Plain

by
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RESEARCH DIVISION

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Introduction

Intensive forest management that includes short rotations and whole tree harvest, followed by site preparation operations such as root-raking and windrowing is common in the Southeast. These intensive management techniques add to the natural growth demands on the nutrient capital of a site. For example, whole tree utilization removes branches and foliage which have high nutrient concentrations per unit biomass. Windrowing concentrates slash, forest floor and often some portion of the topsoil into small areas that are not generally available to the next rotation's trees. Consequently, many scientists and managers have expressed concern that intensive practices may decrease long-term productivity.

In order to make wise long-term decisions, as well as profitable short-term ones, managers need information on nutrient losses due to various management techniques. Few studies have been conducted that describe the nutrient pools in forest stands of Georgia, and fewer still on the removal and redistribution of the nutrients folowing harvesting and site preparation. However, data is available from similar physiographic regions. This paper will use data from several studies to estimate and compare nutrient losses from various harvesting and site preparation techniques for sites typical of the Piedmont and Coastal Plain in Georgia.

Overview

In a natural forest ecosystem, a large proportion of the site's nutrients are retained and recycled. Nutrients in foliage and the woody biomass of a tree are returned to the soil through litterfall, throughfall, stemflow and the eventual death and decay of the trees. Consequently, the decomposing foliage and woody biomass in the forest floor are an important nutrient source. The forest floor is particularly important in Georgia where many managed forests are on the highly eroded clays of the Piedmont or the infertile sands of the Coastal Plain. Harvesting and site preparation techniques disrupt the natural forest nutrient cycle by removing nutrients and redistributing nutrients (e.g., windrowing), which can lead to a short term acceleration of leaching beneath the root zone and/or soil erosion associated nutrient loss.

Though some nutrients such as nitrogen are naturally replaced by atmospheric inputs or fixation, and others (e.g. calcium) are resupplied by the weathering of bedrock and soil particles, such inputs may not offset losses due to management practices. A positive balance of limiting nutrients is important if site fertility is to be maintained over numerous rotations.

Table 1. Sources of data for representative southeastern forest types.

Forest Type	Source	Species	Age	Location
			- yrs -	
Piedmont loblolly	Wells & Jorgenson (1979)	loblolly	16	Piedmont N. C.
	Tew et al. (1986)	loblolly	22	Piedmont N. C.
	Kodama & Van Lear (1980)	loblolly	12-17	Piedmont S. C.
Piedmont hardwood	Johnson et al. (1982)	oak, tulip poplar, red maple, hickory, etc.	50-120	Eastern Tenn.
Piedmont mixed pine/ hardwood	McMinn & Nutter (1983)	oak, hickory, loblolly, shortleaf	40-60	Piedmont, Ga.
	Marion (1979)	hardwoods, conifers	>70	Temperate zone
Coastal Plain slash/	Burger & Pritchett (1979)	slash pine, longleaf pine	45	Florida
	Morris & Pritchett (1982)	slash pine, longleaf pine	40	Florida
Coastal Plain hardwood	Messina et al. (1983)	sweetgum, water oak, green ash, hickory, sycamore	60	Atlantic & Gulf coastal

Data Sources

Several studies of nutrient loss due to management practices in the Southeast were conducted on sites similar to those found in Georgia. We have applied data from these studies to hypothetical sites. Because data have been assembled from various studies and sites, the expressed quantities should be taken to represent trends. Table 1 is a listing of our major sources of data. For convenience, we have divided Georgia into five major economic forest types: in the Piedmont - loblolly, mixed hardwood and mixed pine/hardwood and in the Coastal Plain - slash/longleaf and bottomland hardwood. Although other forest types may have economic importance, little or no data exists on nutrient losses resulting from management activities. The mountain region was not included due to the lack of data and the use of less nutrient demanding methods of harvesting and site preparation.

Discussion

Table 2 gives estimated pool size of each nutrient for the various stand components of the five forest types. The table illustrates the importance of the forest floor and the canopy as nutrient storage sites, averaging 47 and 39% of the whole tree values, respectively. The forest floor is particularly important for nitrogen (N) and phosphorous (P). For most forest types, an intact forest floor can help compensate for N losses due to conventional harvest because the forest floor acts as a buffer, slowly releasing N as it decomposes over the course of the next rotation's growth (Morris and Pritchett, 1982). Although the largest reserve of P is found in the soil, the forest floor is a major source of

Table 2. Representative nutrient masses for stand components of five forest types.

Forest type	Component	Biomass	N1)	P	K	Ca	Mg
		-(t/ha)-			(kg/ha)		
Piedmont loblolly	Tree: whole	156	257	31	165	187	46
	bole	125	115	15	89	112	30
	crown	31	144	16	76	75	17
	Forest floor	-	307	30	28	93	20
	Soil (extract.) 0 - 44 cm 2)	-	1753	371	404	3131	424
Piedmont hardwood	Tree: whle	183	403	30	192	1180	-
	bole	141	150	17	90	935	-
	crown	41	153	12	87	2345	-
	Forest floor	13	150	11	25	205	-
	Soil (extract.) 0 - 45 cm 3)	-	3100	33	280	435	-
Piedmont mixed pine hardwood	Tree: whole	-	381	19	131	637	-
	bole	-	168	11	65	368	-
	crown	-	213	8	66	269	-
	Forest floor	-	236	12	24	79	-
	Soil (extract.) 0 - 50 cm 4)	-	7050	12	446	334	-
Coastal Plain slash/longleaf	Tree: whole	74	110	10	36	118	27
	bole	65	66	6	22	90	20
	crown	9	44	4	14	28	7
	Forest floor	34	271	10	9	96	20
	Soil (extract.) 0 - 20 cm 3)	-	1139	7	28	157	50
Coastal Plain hardwood	Tree: whole	377	387	52	360	997	93
	bole	309	189	22	236	746	29
	crown	68	198	29	124	251	63
	Forest floor	-	59	6	17	91	13
	Soil (extract.) 0 - 30 cm 6)	-	-	21	170	1636	231

1) N is total N
2) N - macro-kjeldahl, P - Hcl & NH F, K, Ca & Mg - NH OAc at ph 7
3) N - Kjeldahl, P - perchloric digestion, K, Ca & Mg 4 ammonium acetate
4) N - Kjeldahl, K & Ca - double acid extraction
5) N - macro-Kjeldahl, P, K, Ca & Mg - double acid extraction
6) Available nutrients NC Dept. Ag., Ag. Div.

Table 3. Percent nutrient loss from various site preparation techniques and conventional harvest versus whole tree harvest. Whole tree harvest with foliage is considered the base of 100%.

Forest type		Treatment	N	P	K	Ca	Mg
			--------------	percent	--------------		
Piedmont loblolly	-	merchantable stem 1)	32	28	35	42	39
		stem/burn 1)	50	35	45	52	56
	-	stem/burn & chop 2)	57	26	39	29	40
	-	stem/shear-pile & disk 2)	395	242	173	270	251
	-	whole tree/burn & chop 2)	103	100	100	100	100
	-	whole tree/ shear-pile & disk 2)	393	242	174	267	251
Piedmont hardwood	-	merchantable stem 3)	33	50	42	71	-
Piedmont pine/ hardwood	-	merchantable stem 4)	39	52	44	51	-
	-	winter whole tree 4)	83	89	92	87	-
Coastal Plain slash/ longleaf	-	merchantabhle stem 5)	53	53	54	68	66
	-	stem/burn & chop 6)	61	50	33	-	-
	-	stem/burn chop & windrow 6)	371	230	141	-	-
Coastal Plain hardwood	-	merchantable stem 7)	43	38	58	67	28

Merchantable stem calculated as 89% of the bole values.

1) Wells & Jorgenson, 1979; Kodama & Van Lear, 1980
2) Tew et al., 1986
3) Johnson et al., 1982
4) McMinn & Nutter, 1983
5) Pritchett & Smith, 1974
6) Burger & Pritchett, 1979
7) Messina et al., 1983

available P. This source is particularly important in the Coastal Plain where P is often the growth limiting nutrient and reserves are low in the sandy soils (Pritchett and Morris, 1982).

The canopy is a more important nutrient pool for hardwood forest types than pine. Because foliage has a high nutrient concentration, the canopy contains more nutrients in the summer than the winter. For most forest types, the canopy is an important storehouse for calcium (Ca).

The data in Table 2 was used to compare the influence of various site preparation and harvesting methods on nutrient removal, loss and/or displacement. For purposes of comparing sites and management practices, above-ground nutrient removal by whole tree harvesting with foliage is represented as a base of 100% in Table 3. Nutrient losses from other management practices are expressed as a percentage of the whole tree removal. For example, the N loss from a conventional harvest on the Piedmont - loblolly pine site would be 32% of the N loss resulting from a whole tree harvest at the same site.

As one would expect, conventional harvest of merchantable stems creates the least demand on nutrient capital, averaging 47% of the losses resulting from whole tree harvest. In general, the nutrient loss per unit biomass is two to four times greater for whole tree harvest (Pritchett and Morris, 1982). The actual percent loss will vary with species and season. Nutrient losses from whole tree harvest of hardwoods are higher than pines with removals from summer whole tree harvests of hardwoods exceeding those from winter harvests. The nutrient loss of whole tree harvest is least in the Coastal Plain - slash/ longleaf forest type due to sparse crowns with low nutrient contents. However, the low nutrient reserves of these sites make them susceptible to P and potassium (K) depletion.

Site preparation by burning or roller chop/burning in Piedmont and Coastal Plain pine sites increases N loss due to volatilization during the burn. The amount of N lost is variable depending on the burn temperature and site conditions. However, these methods of site preparation do not dramatically increase other nutrient losses. Losses due

Table 4. Nutrient removals, loss and displacement on a Piedmont loblolly pine site. 1)

Management practice	N	P	K	Ca	Mg
	------------------ kg/ha ------------------				
Conventional harvest	102	13	79	105	27
Chop & burn	45	2	12	12	9
Total	147	15	91	117	36
Whole tree harvest	257	31	165	187	46
Chop & burn	45	2	12	12	9
Total	302	33	177	199	55
Conventional harvest	102	13	79	105	27
Shear-pile/disk	654	41	118	429	74
Total	756	54	197	534	101

1) Harvest removals from Table 2, burn losses from Kodama & Van Lear, 1980, shear-pile/disk displacements and losses from Tew et al., 1986.

to these methods coupled with a conventional harvest average 44% of whole tree harvest losses.

By far the largest loss of available nutrients occurs with a shear-pile/disk site preparation, if nutrient displacement into windrows are considered "lost" to the majority of trees on a site. The displacement of the forest floor, a portion of the topsoil and organic residues into the windrows overshadows whole tree harvest losses. Indeed, if this type of site preparation practice is used there is little difference in nutrient loss due to harvesting method. In addition, the estimated losses due to shear-pile/disk do not include potential losses due to erosion that may occur with this intensive practice.

Losses from management practices can be replaced by atmospheric inputs, fixation and weathering. Data on inputs are scarce and the amount of nutrients replaced will vary from site to site due to proximity of industrial centers, the ocean, moisture regime, soils and bedrock materials. This makes generalizations about the long term productivity difficult. However, evidence indicates that shear-pile and disk site preparation is detrimental to site productivity. For example, research in Florida flatwoods found atmospheric inputs of N over a 25-yr rotation were 163 kg/ha (Riekerk, 1982) and N fixation of 60 kg/ha (Pritchett and Morris, 1982) compared to losses of 488 kg/ha by harvest with shear-pile and disk site preparation (Morris and Pritchett, 1982; Morris et al. 1983). Pritchett and Morris (1982) state productivity in Coastal Plain sites will decrease under this type of intensive management and fertilization will be needed to replace P and base cations. Although soil reserves are higher in the Piedmont, Tew et al. (1986) conclude losses from shear-pile and disk are "unacceptable".

Example

Though the data presented here were assembled from different studies, managers can use trends to help guide their decisions. For example, suppose a manager has a mixed pine-hardwood stand in the Piedmont that he wants to convert to pine. If the stand is harvested conventionally, he may prescribe an intensive site preparation, i.e. shear-pile/disk to reduce hardwood competition and to make the site easier to plant. However, these management practices will remove or displace two times the amount of N and P than if he used a whole tree harvest with a roller chop and burn to achieve the same objectives. A conventional harvest with shear-pile/disk will remove two to five times more nutrients than a conventional harvest with roller chop and burn (Table 4).

Conclusions

Data representative of five economically important forest types indicate conventional harvest leaves the most nutrients on a site, thus has the least potential effect on site productivity. Whole tree harvest removes two to four times the nutrients per unit biomass as conventional harvest. Increased utilization in harvest may be justified by decreases in intensive site preparation (Tew et al., 1986) or to improve the silvicultural condition of the stand (Phillips and Van Lear, 1984). Site preparation by shear-pile and disk removes two to seven times the amount of nutrients as roller chop and burn. Several studies indicate continued use of shear-pile and disk may lead to decreases in site productivity and the need for fertilization if productivity is to be maintained over the long run.

LITERATURE CITED

Burger, J. S., W. L. Pritchett. 1979 Clearcut harvesting and site preparation can dramatically decrease nutrient reserves of a forest site. In: Proceedings, Impact of intensive harvesting on forest nutrient cycling. College of Environmental Science and Forestry, SUNY; Syracuse, N.Y. p. 393-403.

Johnson, D. W., D. C. West, D. E. Todd, and L. K. Mann. 1982. Effects of sawlog vs. whole-tree harvesting on the nitrogen, phosphorus, potassium, and calcium budgets of an upland mixed oak forest. Soil Sci. Soc. Am. J. 46: 1304-1309.

Kodama, H. E. and D. H. Van Lear. 1980. Prescribed burning and nutrient cycling relationships in young loblolly pine plantations. South. J. App. For. 4:118-121.

Marion, G. M. 1979. Biomass and nutrient removal in long-rotation stands. In: Proceedings, Impact of intensive harvesting on forest nutrient cycling. College of Environmental Science and Forestry, SUNY; Syracuse, N.Y. p. 98-110.

McMinn, J. W. and W. L. Nutter. 1983. Nutrient removal under whole-tree utilization for fuel chips. Georgia Forestry Commission, Research Divison; Georgia Forest Research Paper 47. pp 7.

Morris, L. A., W. L. Prichett. 1982. Nutrient storage and availability in two managed pine flatwoods forests. In: Proceedings, Impacts of intensive forest management practices. School of Forest Resources and Conservation, U. of Fl; Gainesville, FL. p. 17-26.

Messina, M. G., S. T. Gower, D. J. Frederick, A. Clark, III and D. R. Phillips. 1983. Biomass, nutrient and energy content of bottomland hardwood forests, N. C. State Hardwood Cooperative Series no. 2.

Phillips, D. R. and D. H. Van Lear. 1984. Biomass removal and nutrient drain as affected by total-tree harvest in southern pine and hardwood stands. J. For. 82:547-550.

Pritchett, W. L. and L. A. Morris. 1982. Implications of intensive forest management for long-term productivity of Pinus elliottii flatwoods. In: Proceedings, Impacts of intensive forest management practices. School of Forest Resources and Conservation. U. of FL; Gainesville, FL. p. 27-34.

Riekerk, Hans. 1982, Water quality management in flatwoods of Florida. In: Proceedings, Impacts of intensive forest management practices. School of Forest Resources and Conservation. U. of FL; Gainesville, FL. p. 53-61.

Tew, D. T., L. A. Morris, H. L. Allen and C. G. Wells. 1986. Estimates of nutrient removal, displacement and loss resulting from harvest and site preparation of a Pinus taeda plantation in the Piedmont of North Carolina. For. Ec. Man. 15:257-267.

Wells, C. G. and J. R. Jorgensen. 1975. Nutrient cycling in loblolly pine plantations. In: Forest soils and forest land management. Laval U. Press; Quebec, Canada. p. 137-159.

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